A Flux Normalization Detector for the COHERENT Experiment #520

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1. INTRODUCTION

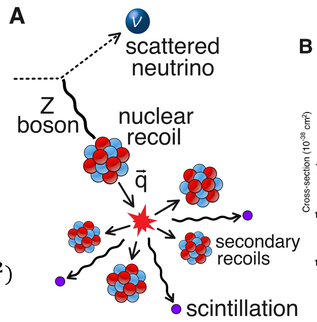
Coherent Elastic Neutrino Nucleus (CEvNS) was first predicted in 1974 [1] and occurs when a neutrino scatters on a nucleus via exchange of a Z boson and the nucleus recoils as a whole. This tiny recoil is the only detectable signature. (see Fig. A).

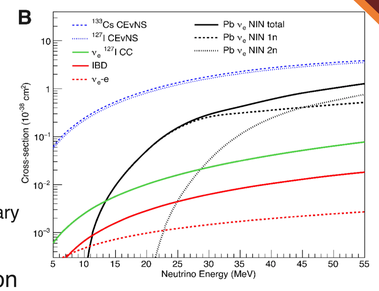
CEvNS:

- Clear prediction in Standard Model (SM).
- Largest of all SM neutrino cross-sections in 1-100 MeV range (Fig. B).
- Cross Section shows an N^2 dependence.

$$\sigma_{tot} = \frac{G_F^2 E_\nu^2}{4\pi}\left[Z(1-4\sin^2\theta_W) - N\right]^2 F^2(q^2)$$

- We need Excellent background rejection and Low-nuclear-recoil-energy threshold detectors for its observation.





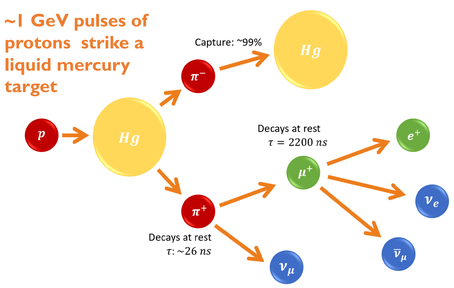
CEvNS AS A PROBE OF NEW PHYSICS

- Non-Standard Interactions
- Sterile Neutrinos
- Dark Matter Search
- Neutrino EM Properties
- Supernovae Studies

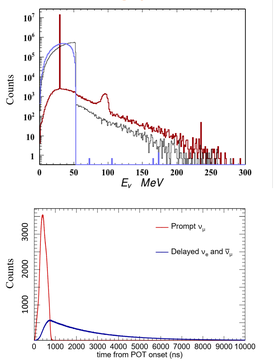
2. THE COHERENT EXPERIMENT

The COHERENT Collaboration made the first measurement of CEvNS in 2017 [2] using neutrinos produced in the Spallation Neutron Source (SNS) in Oak Ridge National Laboratory.

~1 GeV pulses of protons strike a liquid mercury target

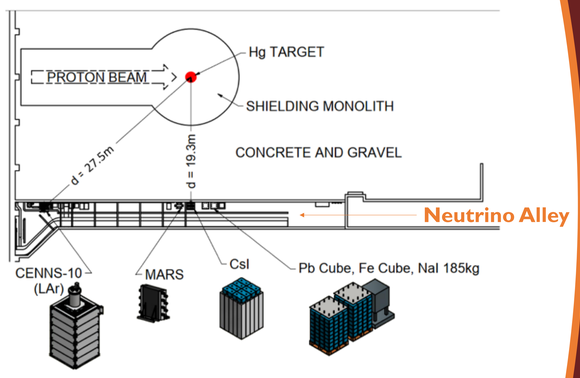


SNS Neutrino Energy and Timing Spectra:



- 2.81×10^{14} ν/cm²/flavor/SNS Year at 20 m
- Monoenergetic ν_μ separated from ν_e and $\bar{\nu}_\mu$
- 0.09 ν per proton-on-target

COHERENT is a suite of detectors dedicated to the study of CEvNS in various nuclei to test the N^2 dependence of the cross section.

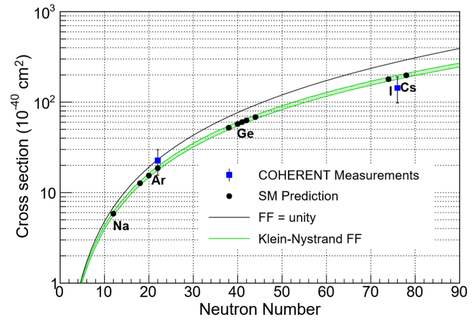


Neutrino Alley is a fully equipped neutrino laboratory, and it is well-shielded from beam related backgrounds

3. MOVING TO A NEW STAGE IN COHERENT

With the first observations of CEvNS on CsI [2] and Argon [3] and planned measurements on other nuclei (Ge and Na), COHERENT is transitioning to a high precision program. Forthcoming CEvNS measurements with increased precision are motivated by physics of interest to a diverse community.

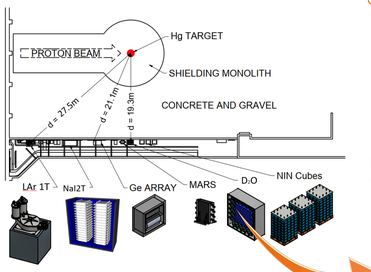
Common for all analyses at COHERENT is the need for the lowest possible flux uncertainty, which is currently estimated to be 10%.



4. A D_2O DETECTOR TO REDUCE FLUX UNCERTAINTY

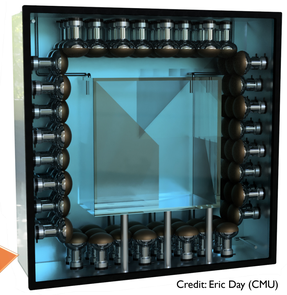
To unlock the high precision CEvNS program, we need to improve the SNS ν flux estimate. We plan to do this via a well-understood process: the Charged Current (CC) cross section for neutrino interactions with deuterium, for which high-precision theoretical calculations exist [4].

Future at COHERENT:



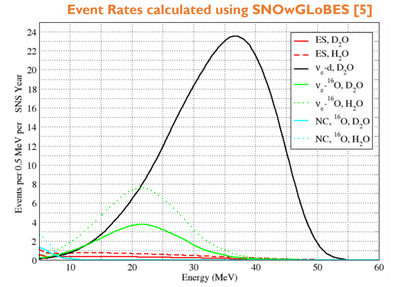
$$\nu_e + d \longrightarrow p + p + e^-$$

Cross Section calculated at ~2% accuracy!



Credit: Eric Day (CMU)

Event Rates calculated using SNOwGLoBES [5]



- Largest beam related background is CC on Oxygen.
- ~930 deuterium events per year.

- The design presented here would allow us to reduce the current flux uncertainty to ~3.5% after two years of data taking.
- Given the neutrino alley space constraints, funding avenues and timelines, other designs involving different geometries and materials are currently under study.

5. SUMMARY

- Common to all COHERENT detectors is the neutrino flux uncertainty. The direct measurement of the neutrino flux will certainly lower the uncertainty and improve precision in all COHERENT analyses.
- Such measurement will be feasible with the deployment of a heavy water detector.
- The D_2O detector is essential to bring COHERENT to the High Precision era.

REFERENCES AND ACKNOWLEDGEMENTS

[1] *D.Z. Freedman, Phys. Rev. D 9 (1974).*
[2] D. Akimov et al. (COHERENT). Science 357, 1123-1126 (2017).
[3] D. Akimov et. al. (COHERENT). arXiv:2003.10630 (2020).
[4] J. A. Formaggio and G. P. Zeller. Rev. Mod. Phys. 84, 1307–1341 (2012).
[5] "Snowglobes" http://www.phy.duke.edu/ schol/snowglobes/, accessed: 2016-02-01.